Metabolic equivalents during the 10-m shuttle walking test for post-myocardial infarction patients

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ABSTRACT

Objective: Comorbidities are found to affect metabolic equivalents (METs). Therefore the main objective of this study was to compare METs (1 MET: oxygen uptake (Vo_2) 3.5 ml/kg/min) during an incremental shuttle walking test (SWT) between non-cardiac and post-myocardial infarction (MI) men, and secondly to determine any differences in Vo_2 (ml/kg/min) between flat treadmill walking and the turning during the shuttle walking in non-cardiac subjects.
Design: Comparative study.
Subjects: Thirty one post-MI (mean (SD) age 63.5 (6.5), range 53–77 years) from phase IV cardiac rehabilitation and 19 non-cardiac (64.6 (7.5), range 51–76 years) men participated.
Methods: All subjects performed an SWT, and non-cardiac subjects a treadmill test of similar protocol. Throughout both, the subject's Vo_2 was measured.
Results: Analysis comparing lines of regression showed METs at 1.12 to 4.16 mph were higher ($p<0.001$) for post-MIs versus non-cardiac subjects. For non-cardiac subjects, there were no differences between the treadmill test and SWT ($p>0.9$) and LoA showed acceptable agreement in METs between treadmill vs SWT, mean difference −1.1 (8.8) (1.96SD).
Conclusion: It would appear that for asymptomatic individuals it is appropriate to apply established METs for flat walking to the SWT. However, the significantly higher METs for the post-MI compared with the non-cardiac subjects indicates the need for caution when using METs derived from healthy subjects in the prescription of exercise for myocardial patients.

The health benefits of physical activity for individuals with coronary heart disease (CHD) are well established,[1] and exercise is now a major component of most cardiac rehabilitation programmes. In order for cardiac patients to achieve favourable physical training responses, and enable the appropriate prescription of physical activities, it is important that each patient's functional physical capacity be established. The British Association of Cardiac Rehabilitation advocates the use of the 10-m shuttle walking test (SWT)[2] for this purpose, and commonly the results are used in the ensuing exercise prescription. The SWT involves walking on the flat between two markers 10 m apart, and at the end of each minute the speed increases. Each test stage has been related to a particular metabolic equivalent (1 MET: oxygen uptake (Vo_2) 3.5 ml/kg/min)[3] so that a participant's functional capacity can easily be established. Metabolic equivalents have been determined for a wide variety of activities and are specific to that particular physical activity.[4] Although MET values were not originally provided with the SWT,[2] the MET values presently used are those obtained from healthy individuals during steady state flat walking.[3] Hence they are not specific to the SWT, which involves turning at the end of each 10-m stretch; requirements very different from walking uninterrupted on the flat. Furthermore, although MET values are reasonably stable between most healthy adults, they can be affected by factors such as age,[5] body weight,[6 7] physical fitness[8] and comorbidities.[9] Given that individuals with CHD tend to be older, less physically fit, overweight and possess numerous comorbidities, it is likely that MET values derived from healthy individuals during flat walking will differ from MET values during the SWT in individuals with CHD.

Furthermore, it is recommended that exercise intensity be prescribed relative to fitness level,[3] and if this level is inaccurate then any following prescribed exercise is likely to be so too. Importantly, inappropriate exercise prescription for cardiac patients based on erroneous METs may result in a miscalculation of their functional capacity, and the prescription of activities that do not result in a sufficient training response, or even place a patient at risk from over-exertion. Health professionals recognise that pathologies affect Vo_2 and need to be accounted for. However, if they are not provided with more population-specific METs they will continue to use those currently available.

As there are no known published data regarding MET values in cardiac patients during shuttle walking, the main objective of the study was to determine more specific MET values for this cohort. Post-myocardial infarction (MI) males make up the greater proportion of the cardiac population and, as this was an initial study, they were considered to be the appropriate subject group. There were two distinct aims of the study: (1) to compare MET values during the SWT between non-cardiac and post-MI men, thus providing cardiac rehabilitation professionals with METs that more specifically reflect their patient cohort; and (2) determine whether shuttle walking differed in MET values compared with walking uninterrupted, thus establishing any effect of turning during the SWT on Vo_2 ml/kg/min.

METHODS

The local NHS research ethics committee and Canterbury Christ Church University Faculty research ethics committee gave approval to the study.

Table 1 Subject characteristics

	Non-cardiac (n = 19)	Post-MI (n = 31)
Age (years)	64.6 (7.5) (51–76)	63.2 (6.5) (53–77)
Height (m)	1.75 (0.05) (1.67–1.88)	1.72 (0.06) (1.64–1.90)
Body mass (kg)	80.7 (13.5) (55–108)	86.7 (14.27) (66–119)
BMI (kg/m^2)	21.2 (3.1) (15.9–27.3)	21.2 (2.4) (14.7–25.4)

Data are presented as mean (SD) (range).

Subjects and recruitment

Thirty one post-MI and 19 asymptomatic age-matched controls (non-cardiac) men participated (table 1). Non-cardiac subjects were recruited from the South East Kent area (UK), and post-MI subjects at the end of phase III cardiac rehabilitation run by the South East Kent Health Promotion Department, UK. The inclusion criteria for the cardiac subjects were non-smoking uncomplicated male MI patients taking aspirin. Potential subjects were given an information sheet. Post-MI subjects were selected and screened from their phase III cardiac rehabilitation and patient notes. Non-cardiac subjects were assessed for health and physical activity using a self-completed questionnaire. All were required to provide written informed consent and their permission for researchers to contact their general practitioner. Volunteers were excluded if their general practitioner was unable to provide participation health clearance and/or if the volunteer was unable to understand the nature of the study. All assessments for post-MI subjects were performed in the afternoon, and non-cardiac subjects were assessed in mornings and afternoons.

10-m shuttle walking test

On two separate occasions, each subject underwent an SWT.[2] The second test was used in the analysis, as research has shown a significant "learning effect" after the first test,[10 11] which appears to abate after the second test.[12 13] Post-MI subjects performed their tests in the Physiotherapy Department at Kent and Canterbury Hospital, UK, and non-cardiac subjects in the BASES-accredited Sport Science Physiology Laboratory at Canterbury Christ Church University, UK. The difference in venue was due to ethically-imposed constraints regarding testing cardiac patients outside of NHS premises. However, both environments were comparable gymnasiums with wooden flooring and of similar dimension. Before each test subjects were seated and asked pre-test screening questions, which took around 5 min. After that, each subject remained seated and blood pressure was determined using a stethoscope and sphygmomanometer (Acconson, Cossor & Son Surgical Ltd, UK); height and body mass were then measured using a stadiometer and clinical scales (Seca 052466, Germany), respectively. Post-MI subjects then lay supine for a 12-lead ECG (P80, Esaotebiomedica, Firenze, Italy), using Q-trace electrodes (Tyco Healthcare, Chicopee, MA, USA). If no additional or acute abnormalities were observed the subject was instructed on the SWT protocol.

Throughout both tests each subject's heart rate (Polar Electro, Kempele, Finland) and $V\text{O}_2$ were monitored breath-by-breath using a portable gas analyser (K4 b^2, Cosmed, Rome, Italy). Information was transmitted via short wave telemetry to a laptop computer. Subjects were instructed to walk between two markers (visible tape on the floor) set 10 m apart in a straight line on the flat. Pre-recorded bleeps on a CD were emitted from a CD player. The timing of the bleeps indicated a specific walking speed and subjects were required to reach the tape in time with each bleep. The test started with a slower speed and fewer shuttles. At 1-min intervals the time between each bleep became faster, indicated by a triple bleep, and the number of shuttles increased (table 2). The test stopped when the subject did not reach the tape in time with the bleep by 1 m on two consecutive occasions, showed signs of physical injury or distress (as indicated by physiological measures of heart rate and respiratory exchange ratio), or no longer wished to continue.

Graded treadmill walking test

It was unfortunate that at the time of carrying out the study that ethical clearance was not granted to test the post-MI patients outside of NHS property. Thus, it was not possible to determine the mechanical effect of the SWT in the post-MI patients. Hence, non-cardiac subjects only completed a treadmill test using similar protocol to the SWT. Each subject was familiarised with the test and performed two tests, which should have been sufficient to substantially reduce any learning effect;[12 13] the second was used in the analysis. The treadmill and SWT were performed in random order as determined by computer.

Subjects walked on a motorised treadmill (Mercury Med, Hp Cosmos, Nussdorf-Traunstein, Germany) starting speed 1.12 mph, using the SWT protocol (table 2). Pre-recorded bleeps on a CD were emitted from a CD player. A triple bleep indicated when to increase the treadmill speed. The criteria for test termination were similar to those for the SWT.

Data analysis

Due to a dearth of MET data during the SWT, retrospective power analysis was performed using the mean difference in MET values during each stage of the SWT between the post-MI and non-cardiac subjects, which ranged from 0.95 METs at level 1 to 2.43 METs at level 9. The Clinstat interactive statistical

Table 2 Protocol for shuttle walk test[2]

ACSM METs[3]	Level	Speed (mph)	Shuttles
3.2	1	1.12	1 to 3
3.4	2	1.50	4 to 7
3.6	3	1.88	8 to 12
3.9	4	2.26	13 to 18
4.2	5	2.64	19 to 25
4.6	6	3.02	26 to 33
5.0	7	3.40	34 to 42
5.5	8	3.78	43 to 52
6.0	9	4.16	53 to 63
6.6	10	4.54	64 to 75
7.1	11	4.92	76 to 88
7.7	12	5.30	89 to 102

Table 3 Number of non-cardiac subjects to achieve walking speeds during the treadmill and shuttle walk test

		Number of subjects to achieve level	
Level	Speed (mph)	Treadmill test	Shuttle walk test
1–6	1.12–3.02	19	19
7	3.40	19	18
8	3.78	18	16
9	4.16	18	15
10	4.54	9	5
11	4.92	1	–

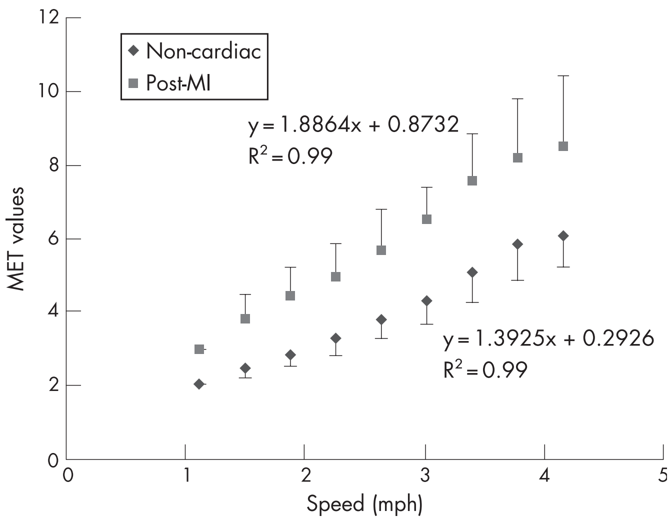

Figure 1 MET values during the shuttle walk test (SWT) for the post-MI and non-cardiac groups. Statistically significant difference between the post-MI and non-cardiac groups during the SWT when comparing two linear regression lines, $p<0.001$.

program by Martin Bland (version 08.05.96) was employed, which established that group sizes at all levels were sufficient to detect differences between tests, if apparent, at a 90% power and an alpha level of 0.05.

Statistical analysis was done using the Minitab statistical package (version 13.32), where a 5% level of significance was used. Variability of data within a distribution was given as one standard deviation (mean (SD)). Differences between group characteristics were compared using Kruskall-Wallis analysis, and the MET versus walking speed relation was determined using analysis comparing two linear regression lines. This analysis separately determined differences in heart rate (beats/min) and V_{O_2} during the SWT between those taking and not taking β-blocker and statin medication.

Agreeability in METs between the treadmill and SWT data was compared using "limits of agreement" (LoA).[14] Pearson product-moment correlations, regression and multiple regression were used to determine relations between factors.

RESULTS

Subject groups

There were no significant differences between the post-MI and non-cardiac subjects in age (years), height (m), body mass (kg) or BMI (table 1).

The subjects were asked to list their non-cardiovascular current comorbidities, and analysis showed that the non-cardiac subjects had a significantly greater amount of comorbidities (1.2 (1.0) (range 0–3) vs post-MI subjects 0.4 (0.7) (range 0–2), $p<0.005$). Additionally, there were no significant differences between the groups in the days of the week they habitually accumulated around 30 min of moderate physical activity, and 20 min of vigorous physical activity (non-cardiac subjects 3.4 (2.3) days (range 0–7 days) vs post-MI subjects 3.5 (3.3) days (range 1–7 days); and non-cardiac subjects 1.2 (1.5) days (range 0–5 days) vs post-MI subjects 0.8 (0.83) days (range 0–3 days), respectively).

Post-MI patients

Patients were tested at around 8–9 months post-MI. Those taking β-blockers (n = 22) displayed significantly lower heart rate (beats/min) values during the SWT versus those not taking β-blockers (n = 9) ($p<0.001$). There was no significant difference between those taking and not taking β-blockers in V_{O_2} (ml/kg/min). Twenty eight (~90%) post-MI subjects were on statin medication. Statin and other medication appeared to have no significant effect upon heart rate or V_{O_2}.[15]

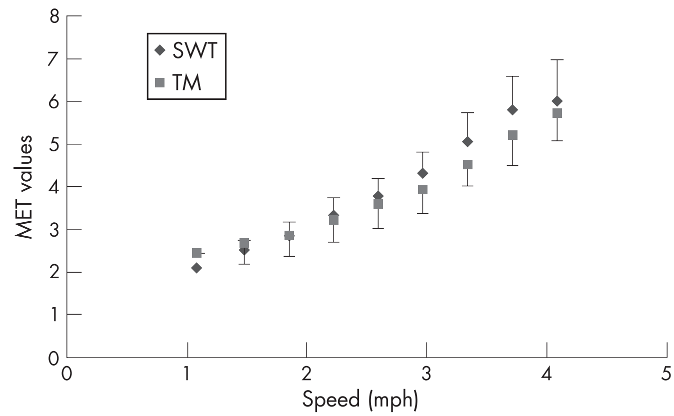

Figure 2 MET values versus walking speed relation for the treadmill TM and shuttle walk test (SWT) in the non-cardiac subject group. No statistically significant difference as determined by comparing two linear regression lines ($F = 8.23$, $p>0.9$).

Shuttle walking test

There were no significant differences between the first and second test in the number of shuttles completed (non-cardiac subjects 55.3 (9.3) vs 56.0 (11.1) shuttles; post-MI subjects, 43.0 (10.9) vs 42.4 (11.6) shuttles). However for both tests non-cardiac subjects performed a greater number of shuttles compared with post-MI subjects ($p<0.001$). All 31 of the post-MI subjects achieved level 5 (2.64 mph); 27 level 6 (3.02 mph); 23 level 7 (3.40 mph); 15 level 8 (3.78 mph); and three level 9 (4.16 mph). All 19 non-cardiac subjects completed level 6; 18 level 7; 16 level 8; and 15 level 9. None of the subjects reached level 11 or above (table 3).

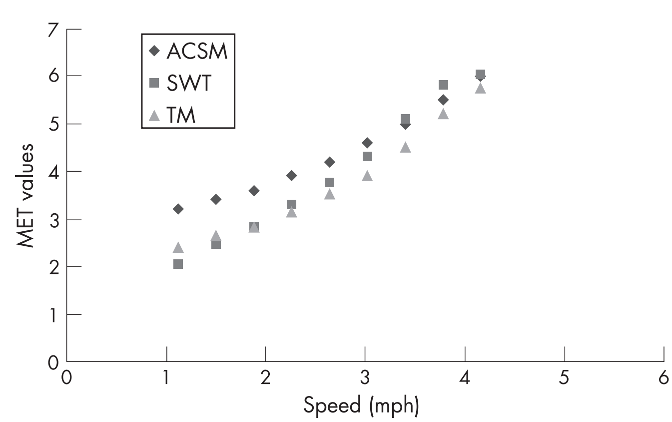

Figure 3 MET values versus walking speed relation for the treadmill (TM) and shuttle walk test (SWT) for the non-cardiac subject group, and mean values during steady state walking on the flat as provided by the ACSM.[3] No statistically significant differences when comparing linear regression lines ($F = 0.575$, $p>0.4$).

METs at walking speeds 1.12–4.16 mph were significantly higher ($F = 0.212$, $p<0.001$) for the post-MI vs non-cardiac subjects (fig 1).

Treadmill and shuttle walking tests (non-cardiac subjects)

Limits of agreement analysis showed acceptability between the treadmill and SWT (mean difference −1.1 (8.8) (1.96SD), 95% CI 7.7 to 9.9), reflected by a strong correlation ($R = 0.88$, $R^2 = 0.48$, $p<0.001$); and supported by lack of significant difference in METs during the treadmill and SWT (fig 2). Additionally, there were no significant differences when comparing METs during the treadmill, SWT and mean ACSM METs for steady state flat walking (fig 3).[3]

DISCUSSION

The METs at shuttle walking speeds 1.12–4.16 mph were significantly higher for post-MI subjects compared to non-cardiac subjects. Various factors, such as environment, fatigue, age, weight, state of physical fitness[8] and inherent personal differences have been found to affect VO_2 (ml/kg/min) in healthy subjects.[16] Differences in bodyweight have been shown to significantly affect METs during walking,[16] and research using healthy weight stable men and women found body composition to account for 62% of the variance in resting measures of VO_2 (ml/kg/min), compared with age, which accounted for 14% of variance.[7] Although our groups did not differ significantly in these variables, the fact that measures of body fat were not taken meant that the contribution of this factor could not be determined.

A potential source of difference in METs may have been the result of disparity in aerobic fitness. Despite there being no significant difference between the two groups in self-reported habitual physical activity levels, the non-cardiac subjects performed a greater amount of shuttles (n = 56) compared with the post-MI subjects (n = 42), indicating that they were physically fitter. Enhanced physical fitness has been shown to reduce VO_2 (ml/kg/min) at similar workloads, and Macko *et al*[17] found, that after six months of three weekly 40-min treadmill sessions in chronic stroke patients, walking economy improved by about 15% (9.3 (2) ml/kg/min to 7.9 (1.5) ml/kg/min). Additionally, seven weeks of running at 80% of initial VO_2max in 13 college-aged males produced between 3.4% and 4.3% improvement in running economy.[18] Biomechanical analysis has shown physically fit individuals to be more mechanically efficient than their less fit counterparts,[19] contributing towards a reduction in VO_2 (ml/kg/min). However, Martin *et al*[20] found this only explained a small proportion of the normal inter-individual variability at any given walking speed. Given that the percentage difference at the various SWT levels ranging from 29% to 35%, even mechanical efficiency and physical fitness could not account for such large differences in the MET values between our groups. Furthermore, the non-cardiac and post-MI subjects had to perform their SWT tests in different venues. Although this may have contributed very slightly to the variation in METs, the environments were very similar, and therefore any difference in VO_2 (ml/kg/min) may be deemed to be small. Therefore despite these confounding factors, their impact can be considered minimal in view of the fact that the non-cardiac subjects did not differ significantly from the norm values provided by the ACSM[3] (figs 2 and 3). This suggests the non-cardiac subjects are representative of a healthy population, and indicates that the difference between the groups was due to components inherent in the post-MI subjects.

Regardless of the fact that the groups did not differ in age, or factors related to BMI, Morris *et al*[5] found that in a group of men (n = 1388, mean age 57 years, range 21–89) free of apparent heart disease (tested for clinical reasons) when compared to similar healthy active (n = 346) and sedentary men (n = 253), the decline in maximal heart rate and METs with age was much greater, suggesting the influence of subclinical comorbidities. This would support the findings of Peterson *et al*,[9] who found multiple comorbidities to potentially cause differences in MET requirements when using the standard MET calculation, rather than a multiple of resting metabolic rate. Comorbidities therefore appear to affect resting metabolic rate, which increases with additional morbidities. When our subjects were asked to list any current comorbidities, other than cardiovascular, they reported conditions from hearing problems to arthritis, but nothing that would seemingly affect their ability to perform the tests. It would have been useful to quantify the effect of the discrete comorbidities on VO_2 (ml/kg/min), however subject numbers did not permit meaningful results. Nevertheless, it was the non-cardiac subjects who possessed the greater number of comorbidities, further indicating that factors related to the post-MI subjects contributed towards the difference in the METs.

The effects of morbidity on measures of VO_2 have been reported in different studies. Dominick *et al* for example found equations based on healthy subjects, such as that of the ACSM to predict VO_2 (ml/kg/min), to overestimate by more than two METs in 202 primary hypertension and 68 fibromyalgia patients.[21] Furthermore, the Ledger equation, derived from healthy subjects to estimate VO_2 (ml/kg/min) during the 20-m SWT, to be invalid in cardiac patients.[22] Where direct measures of VO_2 peak are not taken, researchers have endeavoured to determine normative peak VO_2 values for cardiac patients.[23] However, due to the nature and treatment of cardiac patients it was recommended that, where possible, direct rather than estimates of VO_2max should be used.[24] In reality this is not always possible; therefore better values for estimation of aerobic capacity in cardiac patients are still required.

Medications may also have been influential in the difference in MET values between the non-cardiac and post-MI subjects, especially as 71% of the post-MI subjects were on β-blockers. However, according to our findings these did not appear to affect VO_2 (ml/kg/min), as there were no significant differences in this factor in the post-MI subjects taking and not taking β-blockers. Similarly, other studies have observed β-blocking medication not to affect submaximal VO_2 levels,[22, 25] although β-blockers have been shown to affect VO_2 max.[25] Furthermore, 90% of the post-MI subjects were taking a statin, and although our findings suggest that these did not affect VO_2 (ml/kg/min), they can cause a degree of myopathy.[26] It can therefore be considered that these drugs may have had an indirect effect on VO_2. In addition, some of the patients were taking both drugs, as well as other types of cardiac medication.[15] However, research into the effect of medications on VO_2 during physical activity and exercise is still in its nascent stages and much still remains to be elucidated.

Shuttle walking and treadmill test

The turning at each end of each 10-m length during the SWT appeared to have little influence upon VO_2 (ml/kg/min) in the non-cardiac subjects, since this did not differ significantly between the treadmill and SWT. These findings are similar to those of Moloney *et al* who found a high correlation ($r = 0.91$, $p<0.001$) in VO_2 during SWT and a treadmill test (of similar protocol) in 20 patients with idiopathic pulmonary fibrosis.[27] A

What is already known on this topic

The incremental shuttle-walking test (SWT) is a valid field test for determining functional capacity in symptomatic individuals. Although strong correlations have been found between the SWT and incremental treadmill tests that determine aerobic capacity, no direct metabolic equivalents (METs) have been established for the various SWT stages.

What this study adds

This study shows that for asymptomatic individuals it is appropriate to apply established METs for flat walking to the SWT. However METs during shuttle walking were found to be higher for post-myocardial infarction patients, challenging the validity of using METs gained from healthy individuals in symptomatic populations and highlighting the need for population-specific MET values.

high correlation was also observed between distance covered in the SWT and mean peak V_{O_2} during a treadmill test (modified Naughton protocol) in 25 middle-aged men and women awaiting heart transplant,[28] and similar results have been seen from studies carried out on respiratory and cardiac patients. Singh *et al*[29] found a significant relation ($R = 0.88$) between V_{O_2}max determined from the modified Balke treadmill test and SWT performance in 19 chronic airflow limitation patients; and Green *et al*[30] a significant correlation ($R = 0.78$) between peak V_{O_2} from the SWT (mean 18.5 ml/kg/min) and peak V_{O_2} from a treadmill test (mean 18.3 ml/kg/min) in heart failure patients. Flower *et al*[31] also found a significant relation between three SWTs and V_{O_2} peak ($R = 0.79$, $R = 0.86$ and $R = 0.87$ respectively) during an incremental treadmill test carried out on 39 men and women (61.2 (8.5) years) 6–8 weeks after coronary artery bypass graft surgery.

Even though the agreement between the treadmill and SWT in the non-cardiac subjects was high ($R = 0.88$), only seven subjects achieved the same final walking speed in both tests; with two subjects reaching one higher level in the SWT, and 10 of the subjects exceeding the SWT by either one ($n = 7$) or two ($n = 3$) levels (table 3). This implies that the SWT is not as accurate at determining peak aerobic capacity as a comparable protocol performed on a treadmill. Similarly, Macsween *et al* failed to find a significant linear relation between VO_2 max and shuttles completed in the SWT in 10 cardiac and 10 rheumatoid arthritis patients.[32] Nevertheless the findings from this study show the use of METs for walking on the flat appear to be valid during shuttle walking in healthy subjects.

The implications of the findings of this study are easily demonstrated. For instance, it is common to recommend that a cardiac patient be able to work at five METs before they are considered to be physically fit enough to move from phase III to phase IV cardiac rehabilitation, which is walking at around 4 mph. According to our findings from the post-MI subjects however, walking at 4 mph is closer to eight METs (see fig 1). Given that other physical activities may be prescribed to cardiac patients based on METs, our findings highlight the need for more population-specific MET values to be determined to enable more appropriate exercise prescription for cardiac patients.

In conclusion, the substantially greater MET values from the post-MI subjects during the SWT further challenges the validity of using MET values gained from healthy subjects, and conveys the need for caution in using these values in the prescription of physical activity for MI patients.

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Commentary 1

This paper provides a useful comparison of the intensity of the 10-m shuttle walking test among cardiac patients and age-matched controls. The results suggest that in cardiac patients a given walking speed results in greater than expected metabolic equivalents (METs) than the same speed performed by healthy controls. Although several of the factors which might affect METs were not measured in the study, the findings suggest that clinicians should be cautious in using METs values (derived from healthy individuals) to prescribe exercise for cardiac rehabilitation patients. Given the limitation of prescribing exercise in absolute terms (for example, METs), it may be more appropriate to use relative exercise intensity measures (for example, % HRmax or $\dot{V}O_2$peak) to determine suitable walking speeds for patients with cardiovascular disease and other comorbidities.

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Commentary 2

One of the key aims of a cardiac rehabilitation programme is to promote an active lifestyle. Walking is arguably the most convenient form of exercise for many, and within the context of a rehabilitation programme it is cheap and transferable to a home exercise programme. It is important to assess an individual's exercise capacity before starting an exercise programme for a number of reasons—to identify peak exercise performance for appropriate exercise prescription, safety to exercise and as an outcome measure of the programme. If walking is to be the encouraged mode of exercise it would seem sensible to identify an individual's physiological and symptomatic responses to walking. Cardiopulmonary exercise testing facilities are not widely available and therefore field-based alternatives have been developed. The incremental shuttle walking test (ISWT) was described in the literature in 1992 for the assessment of patients with chronic obstructive pulmonary disease.[1] Since then its use has expanded to other respiratory and cardiac conditions.[2] The paper by Woolf-May and Ferrett describes the metabolic equivalent (MET) calculated for discrete levels of the ISWT patients post-MI. MET data from healthy individuals could potentially be used to guide physical activity, however the authors questioned the validity for this population.

The results revealed that there was a significant difference in MET levels achieved across a range of walking speeds on the ISWT, being higher in the post-MI population. A number of reasons are discussed as to why this might be—one being lack of fitness! It is interesting that the post-MI patients have a much reduced exercise capacity compared with the healthy control subjects that persisted even after a phase III programme. The participants were reportedly completing regular bouts of moderate or vigorous physical activity, but perhaps they were not vigorous enough to improve their overall level of fitness.

The implications of this paper are clear: if the ISWT is used to prescribe a walking regime, a safe and effective regime is easy to prescribe from the results of this test. It is acknowledged that the physiological response to walking and cycling is different and therefore caution is needed if the data from an ISWT are used to prescribe an alternative exercise regime.

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